Chapter 2 – Conceptual Models

INTRODUCTION

A conceptual model is a visual and/or narrative summary that describes the important components of an ecosystem and the interactions among those components (NPS 2003). It is, by nature, a simplification of a complex system that may be imperfectly or incompletely understood (Starfield 1997). By using models to synthesize current scientific understanding, field observation, and professional judgment, it is possible to make reasonable decisions on what to monitor and how the variables being monitored are linked within complex ecosystems (Maddox et al. 1999, DeAngelis et al. 2003). This chapter summarizes the process used to develop and use conceptual models in the selection of Vital Signs appropriate to the GLKN parks.

The Purpose of Conceptual Models in Vital Signs Monitoring

Conceptual models serve at least three functions in the development and application of monitoring programs (after Maddox et al. 1999):

- A model summarizes the most important ecosystem descriptors, spatial and temporal scales of biological processes, and current and potential threats to the system.
- A model plays an important role in determining indicators for monitoring.
- A model is an invaluable tool to help interpret monitoring results and explore alternative courses of action.

One goal of monitoring Vital Signs is to provide park managers with the information necessary to evaluate the effectiveness of management actions. The relationships between societal values protected in parks and ecological integrity must be understood among all parties (Noon 2003). Conceptual models provide the means of communicating about the myriad components in an ecosystem and the complex interactions among the natural and anthropogenic processes in that ecosystem.

Conceptual models are not ends in themselves, but rather are a tool for organizing and illustrating knowledge of priority resources at suitable spatial and temporal scales (Maddox et al. 1999). Well-designed conceptual models (NPS 2003):

- Formalize current understanding of system processes and dynamics
- Identify linkages of processes across disciplinary boundaries
- Identify the bounds and scope of the system of interest
- Contribute to communication among all parties.

MODEL DEVELOPMENT

Ecosystems and Authorship

Network staff met with the Technical Committee in the spring and fall of 2002 to select a modeling approach and identify the environmental components to be modeled. The Committee determined that GLKN park ecosystems would be adequately addressed through six broad conceptual models: Great Lakes, inland lakes, large rivers, wetlands, northern forests, and geological processes. Network staff enlisted scientists with good knowledge of these ecosystems and a familiarity with the Network parks to write the conceptual models (Table 8).

Table 8. Great Lakes Inventory and Monitoring Network conceptual models authors and affiliations.

Model	Author
Geological processes	Walter Loope, Ecologist, USGS Great Lakes Biological Station
Inland Lakes	Paul Sager, Professor Emeritus, UW-Green Bay
Great Lakes	Glenn Guntenspergen, USGS Patuxent Wildlife Research Center
Large Rivers	Ken Lubinski, USGS Upper Midwest Environmental Sciences Center
Northern Forests	Jerry Belant, NPS Pictured Rocks National Lakeshore Phyllis Adams, NPS Midwest Regional Office
Wetlands	Joan Elias, NPS Great Lakes Inventory and Monitoring Network Darin Carlisle, USGS Water Resources Division

Type of Model Used

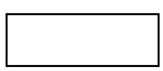
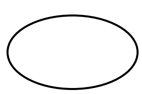
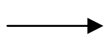
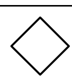
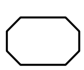
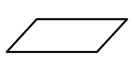
Considerable discussion and analysis of model types and their usefulness in developing monitoring programs appears in ecological literature (Maddox et al. 1999), NPS I&M Program guidance documents (Gross 2003, Plumb 2003), and in monitoring plans for other NPS networks. Instead of reproducing that discussion here, the characteristics and usefulness of the most frequently used conceptual models are summarized in Table 9.

The GLKN, through its Technical Committee, selected a stressor-based modeling approach. Model authors were asked to produce a narrative report with box and arrow schematics to represent key ecosystem components and linkages (Table 10). We felt the combined strengths of the narrative and box and arrow diagrams helped convey important information and provided clear links to management issues (often drivers and stressors in the system).

Table 9. Comparison of common types of conceptual models.

Type of model	Description	Strengths	Drawbacks
Narrative	Uses word descriptions, mathematical or symbolic formula	Summarizes literature and is information rich	No visual presentation of important linkages
Tabular	Uses tables or two-dimensional arrays	Conveys the most information	May be difficult to comprehend the amount of information
Picture models	Depicts ecosystem function with plots, diagrams, or drawings	Good for portraying broad-scale patterns	Difficult to model complex ecosystems or interactions
Box and arrow (Stressor model)	Reduces ecosystems to key components and relationships	Intuitive, one-way flow, clear link between stressor and Vital Signs	No feedbacks, few or no mechanisms, not quantitative
Input/output matrix (Control model)	Box and arrow with flow (mass, energy, nutrients, etc.) between components	Quantitative, most realistic, feedback and interactions	Complicated, hard to communicate, state dynamics may not be apparent

Table 10. Components of the "Box and Arrow" conceptual models used by the Great Lakes Inventory and Monitoring Network in identification of Vital Signs (adapted from NPS 2003).

Symbol	Model Component
	*Drivers* are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.
	*Stressors* are physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include air pollution, water pollution, water withdrawal, pesticide use, timber and game harvest, and land-use change. They act together with drivers on ecosystem attributes.
 or 	*Ecological effects* are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.
	*Attributes** are any living or nonliving environmental feature or process that can be measured or estimated to provide insights into the state of the ecosystem.
	*Measures* are the specific variables used to quantify the condition or state of an attribute or indicator. These are specified in definitive sampling protocols. For example, stream acidity may be the indicator; pH units are the measure.

* Vital Signs are a subset of attributes that are determined to be the best indicators of ecological condition, or respond to natural or anthropogenic stresses in a predictable or hypothesized manner, or have high value to the park or the public (e.g., endangered species, charismatic species, exotic species).

Results Of Modeling

The six conceptual models are presented in their entirety in Gucciardo et al. (2004) and a brief overview is provided below.

The conceptual models provide important background information on how ecosystems function, give specific examples of the most prominent causes of changes, and reference the most significant literature. For example the Wetlands Model provides this discussion on water levels:

> *"The magnitude, frequency, duration, timing, and rate of change of water levels are known as the hydrologic regime (Poff et al. 1997). Factors influencing the hydrologic regime include landscape position, soils, underlying geology, precipitation patterns, groundwater relations, and surface water runoff patterns (Tiner 1999). The hydrologic regime affects soil bio-geochemical processes, nutrient cycling, and nutrient availability. These processes, in turn, influence the biological communities that can be supported in a wetland. Hydroperiod - the duration, frequency, and timing of water level fluctuations - varies among wetland types and, in part, determines wetland type."*

In addition to the descriptive information, the models provide a diagrammatic view of how various drivers, stressors, attributes, and measures are linked (Figure 3). These simplistic models may need to be refined and expanded as the Network develops specific monitoring questions, but in their current form they illustrate the major causes of change (drivers and stressors) and how multiple lines of evidence could be used to monitor such change. To illustrate, in the Inland Lakes Model (Figure 3), atmospheric deposition leads to toxic loading and ecosystem contamination, which in turn affects organism health that can be measured by body burdens of toxics in fish and wildlife. The author suggests that body burdens are the most efficient means of measuring the effects of atmospheric deposition, however, monitoring could occur directly at the driver or stressor level as well. In many cases, it is these multiple lines of evidence that will be important, because cause and effect relationships are difficult to determine conclusively through monitoring data.

To summarize the model results, Network staff grouped the drivers and stressors identified by the models into categories reflecting major "causes of change" (Table 11). This is consistent with the definition we provided to model authors for drivers and stressors, which "act together to cause change in ecosystems" (Table 10; see also Noon 2003). The modelers often grouped (lumped and split) drivers and stressors in different ways or named them differently. To provide a consistent summary we used coarse groupings and a liberal interpretation of the authors' terminology to capture the major causes of change. For example, neither "climate" nor "weather" was specifically named as a driver or stressor in the Earth Processes Model, yet *weathering* (referring to erosion), *wind*, and *wave action* were discussed. Because these processes are influenced by climate in the long term and weather patterns in the short term, we included "climate/weather" as a cause of change identified by the Earth Processes Model. We treated the other model terminology similarly. The results suggest there are 11 major causes of change in the Great Lakes Network parks, and that four (climate/weather, human development, human use, and polluted air and water) influence all six of the major ecosystems modeled.

Table 11. Generalized ecosystem stressors as presented in six conceptual models representing ecosystems of the Great Lakes Inventory and Monitoring Network parks.

	Conceptual Models[1]						
Causes of change[2]	**Great Lakes**	**Inland Lakes**	**Large Rivers**	**Wetlands**	**Northern Forests**	**Earth Processes**	**No. models**
Climate and weather	X	X	X	X	X	X	6
Human development	X	X	X	X	X	X	6
Human use	X	X	X	+	X	X	6
Polluted air and water	X	X	X	X	X	+	6
Exotic and invasive species	X	X	X	X	X		5
Erosion and sedimentation	+	X	X	X		X	5
Water levels	X	+	X	X		X	5
Natural biotic processes	X	+	+	X	X		5
Habitat loss and alteration	+	+	+	+	X		5
Fire and fire suppression		X		X	X	X	4
Natural physical processes	X		X			X	3

1 = An “X” indicates that the model author(s) identified the cause of change as a driver or stressor in the model while a “+” indicates those Network staff added for consistency.

2 = Cause of change is used here to include all drivers and stressors which act together to cause change in an ecosystem.

Causes of change can be completely natural, that is, ‘natural biotic processes’ such as predation, disease, and herbivory. They can also be anthropogenic, such as ‘human use’ including harvest and recreation. Finally, some of the major causes of change can be both natural and anthropogenic. ‘Habitat loss and alteration’, for example, includes natural forest succession along with human-induced changes.

Over 70 ecosystem attributes and more than one hundred measures were identified by model authors. Although differences in the naming and grouping of attributes and measures make it difficult to summarize here, the attributes and measures identified in the models, together with the monitoring issues and questions from park scoping, were the raw material from which candidate Vital Signs were chosen. Network staff narrowed this extensive list down to 40 candidate Vital Signs and presented it to park managers and scientists within and outside of the NPS at a series of meetings. Participants at these meetings used the models, their professional experience, and other information to discuss, revise, and score the candidate list according to predetermined criteria. The Network revised the list based on these discussions and then combined scores to determine the final prioritized list of Vital Signs for long-term monitoring. A complete presentation of the process and results is the topic of Chapter 3.

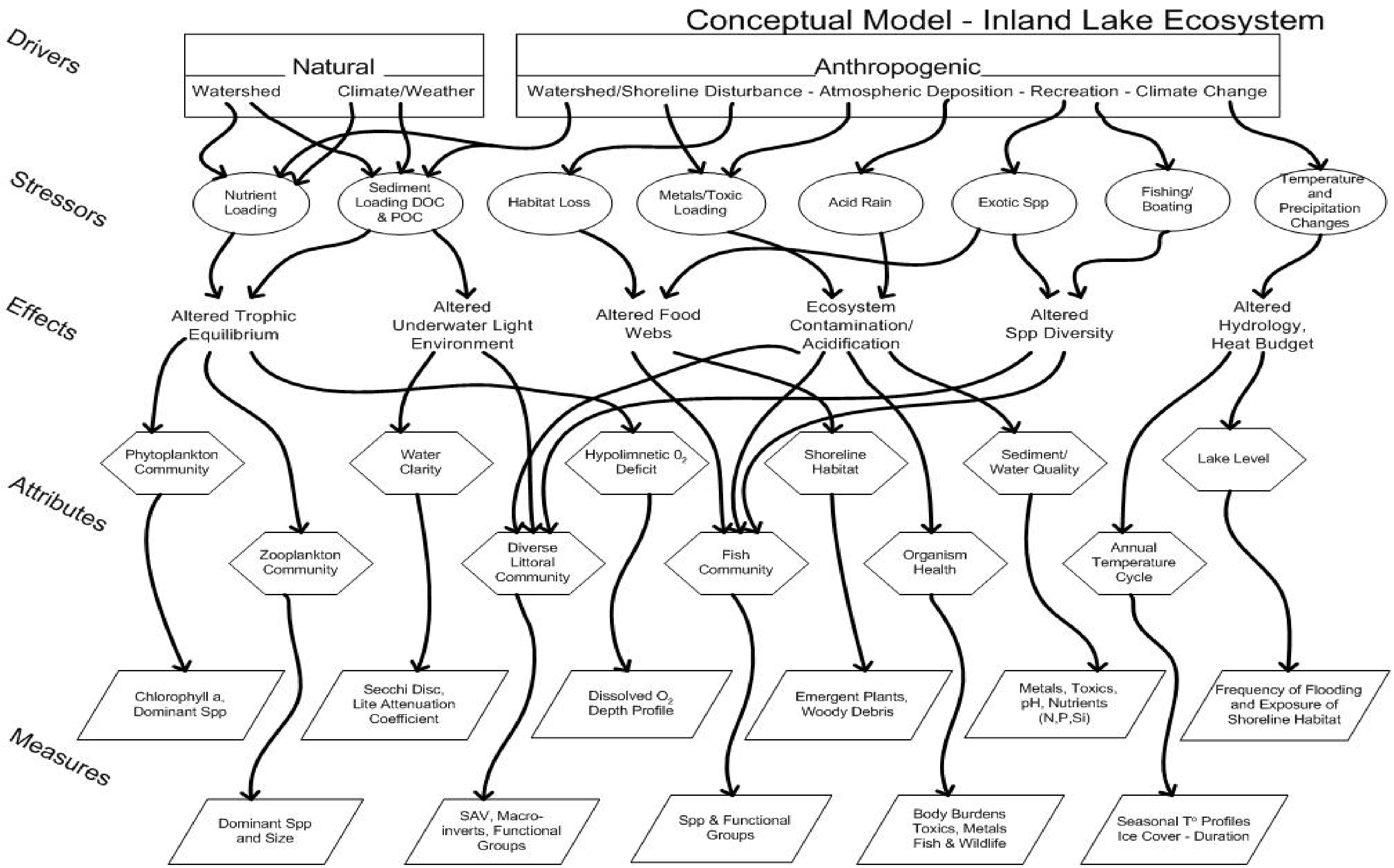


Figure 3. Diagram from the Inland Lakes Conceptual Model showing linkages among drivers, stressors, attributes, and measures.